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TWO WAY CABLE SYSTEM WITH NOISE-FREE RETURN PATH

FIELD OF THE INVENTION

This invention relates to cable systems and more particularly to such systems with a sufficiently noise free return path to support two-way broadband, multimedia content delivery to and from the home.

BACKGROUND OF THE INVENTION

It is well known that the return path in a cable system is noisy and is frequently referred to as a "noise funnel". There are three primary sources of such noise: Thermal, fiber optic link and ingress. Thermal noise is generated in each of the active components (amplifiers and receivers). The fiber optic link noise is generated in the return laser, fiber and headend receiver. Ingress noise arises through home wiring and connections and constitutes the major source of noise. A complete discussion of the return path and the noise characteristics is provided in "Return Systems for Hybrid Fiber/Coax Cable TV Networks" by Donald Raskin and Dean Stoneback, 1998 Prentice Hall, Inc.

Every cable system has a major trunk along which signals are transmitted from a headend in a forward direction to set-top boxes located in homes or business facilities connected to the feeder lines. Connection of set-top boxes to a feeder line is provided by connecting each set-top box to the feeder line via a tap. In the usual organization of a cable system there are many set-top boxes connected to each feeder line. Moreover, each feeder and/or trunk line includes bi-directional amplifiers which pass signals in a high frequency band in the forward (downstream) direction and in a low frequency band in the return (upstream) directions, which is well understood in the art. Signals in the low

frequency band originate at set-top boxes and are used to communicate in the upstream direction to the headend.

The problems with present return paths in cable systems arise from the fact that the path from the set-top to the tap in the feeder line (the inside wiring and the drop) is characterized by an unacceptable level of noise (ingress) which is picked up in the home wiring and in drop cable in the low frequency band where the set-top box transmits. Further, no other band (relatively free of such ingress noise) in a low-split cable system is available for transmission from the home to the headend. Present low-split cable systems are wedded to transmission from the cable headend in a high frequency band and transmissions from set-top boxes in a low frequency band.

Yet the financial expectations of two way, broadband channels via a cable system are so compelling that significant resources are being dedicated towards solving the ingress noise problems in the return paths. The present remedial solutions are expensive, cause system shut down, cause system instability, require repeated service calls to subscribers facilities, and frequent home and drop rewiring or installation of special traps. Moreover, with corrosion and deterioration of lines and connectors, there is a high likelihood that continued attention by cable operators will be necessary.

In the last ten years the cable industry has been retrofitting its cable infrastructure to allow for two-way communications on the cable plants. This is referred to in the industry as activating the return path, the return path being in the 5-40 MHz frequency band. The design of the return path started with rebuilds in the late 70's. In the late 80's the bigger cable companies began to segment their service area into smaller groups called "nodes", and changed their trunk system in many cases from using just co-axial cable and

trunk amplifiers to a hybrid fiber/co-axial cable system (HFC). At the same time active and passive devices were replaced to increase the frequency spectrum in the downstream direction from 50-350 MHz plants to 50-750 MHz, in some cases up to 850 MHz. The increased downstream frequency band allows cable companies to offer more channels of video services. The increased bandwidth also can be used for digital services in the forward direction. Also, by now activating the return path, two-way services such as impulse pay-per view, interactive TV, cable modems, telephone service, and additional services can be offered.

In the activation of the return path, it has been found by most of the cable companies, that the 5-40 MHz frequency band, especially the 5-15 MHz spectrum is extremely noisy. Because of the presence of the noise, most of the services presently available in the lower frequency band are digital services that can work with low carrier to noise signal levels. But since the noise is not consistent, services are seriously impaired at times. Thus, a large number of cable companies are currently looking for ways to reduce the noise in the 5-40 MHz frequency band. Most of the approaches have been to reduce the number of homes connected to each node thereby reducing the total accumulated noise collected in each segment of the node. There have also been approaches involving the installation of 5-50 MHz blocking filters to reduce the noise from inactive subscriber's homes in the 5-50 MHz frequency band from entering the main cable distribution network. The current best approach is to divide the cable system into many nodes which service as few as fifteen homes which is in effect providing a system of small clusters of homes, each connected directly to the node.

BRIEF DESCRIPTION OF THE INVENTION

The present invention is based on the realization that a portion of the downstream frequency band (i.e. 50-750 MHz) can be used, in part to carry the return path signal from a set-top box. That portion of the frequency band is presently used to provide TV signals and digital signals from the headend to the home. But that portion of the band cannot presently be used to carry return path signals.

In accordance with the principles of this invention, the noise picked up in home appliances, drops, connectors, etc and transported to the corresponding node in the feeder line is avoided by reconfiguring the set-top box to transmit in the high frequency band rather than in the low frequency band where most of the noise occurs. The signals from the set-top box proceed in the downstream direction to the feeder line end, which in addition is equipped with a high-to-low frequency converter and an amplifier to send the signal in the return direction through the return path to the headend. The result is that set-top box transmissions travel in the forward direction to the feeder line end where they are received and retransmitted in a frequency band passed by the "reverse" amplifiers in the feeder line. The noise (home to feeder line tap) is averted and the "reconstructed" return signals are virtually free of ingress noise in the trunk and feeder lines. In this context, each feeder line end has a terminator and the receiver and high-to-low converter may be placed anywhere after the last amplifier in the feeder line and the terminator. The portion of the feeder line between the last amplifier and the terminator is referred to herein as the feeder line end.

Specifically, applicant herein adds to the cable system relatively inexpensive equipment which permits the set-top box to feeder line end portion of the return path to

function as a forward path. This is accomplished, in one embodiment, by providing at each feeder line end a receiver and a high to low frequency converter. The receiver receives the signals in the high portion of the band and the converter converts the signals to the 5 to 40 MHz band for transmission back to the node. The nature of the system is that it virtually eliminates ingress noise from house wiring and the drop, which is shown schematically on page 57 of the above-noted publication.

A high pass filter is added between each tap to the feeder line and the set-top box or any other device(s) in the home. This is to ensure that signals in the low frequency portion of the frequency band are blocked from entering the feeder line and only the high frequency signal used by a set-top box are allowed to enter the feeder line.

In another embodiment, each feeder line end includes a receiver and a demodulator to decode the received data. The decoded data is then used to modulate a signal in the lower frequency band. The regenerated signal does not contain the noise that was contained in the received signal. It is in effect a noise free signal.

Thus, in accordance with the principles of this invention, a technique is provided for eliminating the ingress noise in the low frequency band from house wiring, device(s) in the home, and the drop from entering the cable system, thus making the low frequency band much more usable for the return path. Due to the noise reduction, the low frequency band can be used for much higher modulation schemes such as QAM-16, QAM-32, QAM-64 etc. Current modulation schemes also become much more reliable and have much lower bit error rates. Overall it makes the return path in a cable system much more usable. With the resulting higher reliability there is likely to be fewer customer calls for

service and higher customer satisfaction. With the lower noise level, the low frequency band can be utilized to carry even video channels.

This invention, illustratively, utilizes a portion of the 50-750 MHz frequency band to carry the return signal from the subscriber locations, rather than the 5-40 MHz frequency spectrum. But the return signal is transmitted first forward to the feeder line end and then back to the cable headend. At the end of each of the feeder lines is a receiver that operates, illustratively in the 50-750 MHz band to receive the "return" signal. For example, the 300-335 MHz band could be used to carry the return signal "forward" to the feeder line end. The signals in this band are received by the receiver at the end of the feeder line. The signals are down converted to the 5-40 MHz frequency band and sent back along the feeder line (bypassing the drops) to the cable headend.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic representation of a prior art cable system including cable headend, trunk, nodes and illustrative set-top box locations;

Fig. 2 are graphic representations of portions of the frequency band presently used for cable headend, set-top box, and bi-directional amplifier operation in prior art cable systems;

Fig. 3 is a graphic representation of ingress noise for transmissions in the low frequency band of fig. 2;

Fig. 4 is a schematic representation of a cable system with a feeder lines configured in accordance with the principles of this invention;

Fig's. 5 and 6 are graphic representations of portions of the frequency band used for cable headend, set-top box, and bi-directional amplifier operation in cable systems in

accordance with the principles of this invention and the ingress noise with respect to transmissions in those portions;

Fig. 7 is a graphical representation of the function of a high-to-low frequency converter in the system of fig. 4;

Fig. 8 is a graphical representation of the function of a band stop (notch) filter in the system of fig. 4;

Fig. 9 is a schematic representation of a prior art set-top box for the system of fig. 1;

Fig. 10 is a schematic representation of a set-top box for a cable system in accordance with the principles of this invention; and

Fig. 11 is a schematic representation of a set-top box for a cable system in accordance with the principles of this invention where the return path is moved all the way up to the high end of the frequency spectrum.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS OF THIS INVENTION

A glossary of symbols and definitions is provided hereinafter as an aid to an understanding of the drawings. The glossary is taken from Modern Cable Television Technology by Walter Ciciora, James Farmer and David Large, Morgan Kaufmann Publishers, Inc., San Francisco, CA 1999.

Fig. 1 shows a schematic block diagram of a prior art cable system to establish a point of reference and terminology for the description of illustrative embodiments of this invention: Specifically, fig. 1 shows a cable system 10 with a cable headend 11 and a major trunk 12. Trunk 12 typically comprises a coaxial cable and is connected to node or hub 13.

Node 13 is connected to the cable headend via optical fiber (or a coaxial cable) 14 and (for the former) includes a laser for providing return signals from a subscriber set-top box to the cable headend.

The major trunk includes a plurality of bi-directional amplifiers represented, illustratively, at 17 and 18. The trunk also includes bridger amplifiers 20 and 21 to which feeder lines 22,23 and 24 are connected as indicated. Also shown is a auxiliary feeder line 26 which also includes bi-directional amplifiers (represented at 27) and tap 28 to which a drop cable 29 to the set-top box is connected.

A cable end is present at the end of trunk 12 as indicated at 30. The end of a feeder line as indicated at 31.

Fig. 2 shows a set of related graphs of signal level versus frequency for the headend, the set-top box, and the bi-directional amplifiers respectively, for a prior art cable system. In the prior art system, the cable headend illustratively, receives signals in the 5–40 MHz band and transmits over the entire, illustratively, 50–750 MHz band. The set-top box operates in just the opposite manner. Specifically, the set-top box transmits in the 5–40 MHz band and receives signals in the 50–750 MHz band.

The bi-directional amplifiers pass signals (forward, away from the headend) in the 50–750 MHz band and pass (return, toward the headend) signals in the 5–40 MHz band. Thus, signals from a set-top box in the 5–40 MHz band occur exactly where most of the ingress noise occurs. Fig. 3 shows a curve 33 representing the accumulated ingress noise with maximum ingress in the 5-40 MHz band. It is clear that the usefulness of the present return path can be severely limited by ingress noise.

Fig. 4 is a block diagram of a cable system in accordance with the principles of this invention. The system 40 comprises a headend 41 connected to a node (or hub) 42 by fiber optic (or coaxial) cable 43. The node contains a return laser (for fiber optic systems). The system also includes a major trunk 45 with bi-directional amplifiers 47 and 48 (there usually are more amplifiers and they are located usually 500-1500 feet apart) with bridger amplifiers 50, and 52. A feeder line 56 is shown connected to bridger amplifiers 50 and terminating at end 58 at which a receiver 59 and a high-to-low converter 60 is located. Similarly, a feeder line 61 has a feeder line end at 62 which includes a receiver 63 and a high-to-low converter 64. High-to-low converters typically include an amplifier to boost signals if necessary.

Receivers 59, 63, 70, and 116 are operative to receive signals illustratively in the 50 to 750 MHz band. The set-top boxes in the system of fig. 4 are also operative to transmit in the 50 to 750 MHz band. Thus, transmissions from a set-top box (the return transmissions) are received first by receivers at the feeder line ends before they are received at the cable headend. Transmissions in the 50-750 MHz band are blocked by the reverse amplifiers in the trunk and in feeder lines and will pass signals in the return path only in the 5-50 MHz band. It is to be understood that in accordance with the principles of this invention, signals from a set-top box are in a frequency band which travels to a receiver at the feeder line end rather than in a return path to the cable headend.

But each feeder line end, also in accordance with the principles of the invention, includes means for receiving those signals and means for converting those signals into signals which are passed and amplified by the amplifiers in the trunk and in feeder lines. In the embodiment of fig. 4, the means for receiving signals in the 50-750

MHz band are receivers 59, 63, 70 and 116. The means for converting those signals into “return path” signals in the 5–40 MHz band comprises high-to-low converters 60 and 64 and additional transmitters if required. Similarly, the modulators 72 and 118 regenerate the data received from demodulators 71 and 117 respectively into return signals in the 5–40 MHz band. The modulators may include amplifiers to boost the signals if required.

Fig. 5 shows a set of related graphs of signal level versus frequency for a cable headend, a set-top box and for a bi-directional amplifier respectively for a cable system in accordance with the principles of this invention. As shown in Fig. 5, the headend receives in the 5–40 MHz band as in the prior art, but does not transmit over the entire 50–750 MHz band. The 300–335 MHz portion is notched out. The set-top box transmits in the 300–335 MHz portion and receives in the 50–300 MHz and in the 335–750 MHz bands. The bi-directional amplifiers, of course, operate as they do in prior art systems to pass “forward” signals transmitted by the headend in the 50–750 MHz band and to pass “return” signals only in the 5–40 MHz band.

It is clear from fig. 5 that signals transmitted by set-top boxes in the system of fig. 4 are not passed by the reverse amplifiers to the headend. Instead, those set-top box transmissions are passed in a “forward” direction to the corresponding feeder line end where they are received, converted to 5–40 MHz signals and retransmitted. The signals now are passed by the reverse amplifiers to bridger amplifier 50 and back to the cable headend.

Fig. 6 shows a graph of ingress noise 100, corresponding to that of fig. 3, along with the portion of the frequency spectrum 300–335 MHz in which set-top boxes transmit in accordance with the principles of this invention. It is clear that ingress noise is

insignificant over the portion of the spectrum now used by set-top boxes in the system of fig. 4.

High frequency to low frequency converters (60 and 64) are operative to convert signals in the 300-335 MHz band to signals in the 5-40 MHz band as indicated in fig. 7. Modulators (72 and 118) generate signals in the 5-40 MHz band. The resulting signals (in the 5-40 MHz band) are send along the feeder line and trunk to the headend, providing return path signals virtually free of ingress noise.

A system, in accordance with the principles of this invention, also includes band stop (notch) filters at the start of auxiliary feeder lines (i.e. 110) in the system to ensure that transmissions from a set-top box in the 50-750 MHz band are only received by one feeder end in the system. Such filters are located at the start of auxiliary feeder line (i.e. 112) to ensure that the signal for each set-top box is received only at one feeder end (i.e. the signal from set-top box 55 is received by receiver 70 only, since band stop filter 112 blocks the signals from being received by receiver 116. High pass or "window" filters are shown at 80, 81, 82, 83, 84 - - - in fig. 4. High-pass filters block out all signals below 50 MHz from entering the feeder line (i.e. blocking out the major ingress noise from entering the feeder line). The window filters block out all of the return band except a window 2-3 MHz wide for analog set-top returns. This allows the old addressable set-top communications to pass while attenuating any other ingress. Fig. 8 shows a graphical representation of a band stop filter which passes signals in the 50-750 MHz band except for signals in the 300-335 MHz (notch) portion of the band. The presence of such filters prevents signals from a set-top box (in the 300-335 MHz band) from being received by more than one feeder end.

Fig's. 9 and 10 show schematic representations of a prior art set-top box and a set-top box in accordance with the principles of this invention, respectively. In the prior art set-top box of fig. 9, a high pass filter 104 excludes signals in the 5–40 MHz band and passes signals in the 50–750 MHz band. The set-top box also includes a low pass filter 101 which excludes signals in the 50–750 MHz band and passes signals in the 5–40 MHz band.

The set-top box of fig. 10 is considerably different. Specifically, the set-top box of fig. 10 includes a band stop filter 102 which passes 50–750 MHz but notches out signals in the 300–335 MHz band. The set-top box also includes a band pass filter 103 which passes signals in the 300–335 MHz band. Thus, the set-top box of fig. 10 receives and transmits in the same (high) band (i.e. 50–750 MHz) whereas the set-top boxes of the prior art receive and transmit in high and low (considerably different) bands respectively. The set-top box also transmits signals in a frequency band which cannot be received by the cable headend.

The converters, demodulators, modulators, receivers, transmitters and other components herein are all commercially available or easily reconfigured from available components by a change in, for example, capacitor values in such components. Any such components operative as required herein may be used in accordance with the principles of this invention.

Fig. 4 also shows an auxiliary feeder line 110 extending from feeder line 66. It is important that a transmission from a set-top box of the system of fig. 4 be received only by the receiver at the end of one feeder line to which the transmitting set-top box is connected. In order to prevent signals from, for example, a set-top box connected to

feeder line 66 being received by a receiver 116 connected to an auxiliary feeder line (110), the auxiliary feeder line includes a band stop filter 112 to exclude such transmissions as discussed herein before.

Alternatively, the cable headend may be configured to poll (i.e. enable) a set-top box and the corresponding feeder line end receiver simultaneously so that only signals from that receiver are received at the headend. The cable headend will of course, require additional software in this case. This would allow the cable operator to choose the size and location of the return frequency band. Frequency agile band stop filters and frequency agile band pass filters can also be used in the system to utilize any portion of frequency band desired by the system operator. The frequency bands selected herein are only illustrative and other bands and/or notches may be suitable as is clear to one skilled in the art. For example, the operator could use the 700 MHz and up band for the return path. In this case the configuration of the set-top box would change to that shown in fig. 11.

It is anticipated that the novel set-top boxes shown herein will have wireless capability added to them to allow them to communicate wireless to other devices in the home and business facilities such as personal computers, videophones, telephone etc.

It is to be understood that although the invention has been described illustratively in terms of a set-top box, any two-way communication device, such as a cable modem, can be used.